DETERMINING THE OPTIMAL LENGTH OF REGULATORY GUARANTEE: A LENGTH-OF-CONTRACT AUCTION[*,†]

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We present an auction design to be used in the area of procurement that allows the length of the regulatory funding period to be determined via an auction. It allows bidders to submit bids against a payment for periods of varying lengths, say 25 and 30 years, instead of a fixed 20-year contract. This can be desirable for securing more favourable terms in financial markets. It yields efficiency and delivers the optimal length of contract, defined as where social value is maximised. The auction is applicable to any infrastructure investment such as energy, transportation or any area that uses contracts.

In most current government procurement tenders, the length of contract is predefined by the government (Engel et al., 2001). Firms have to incorporate this predefined length into their investment plans and bid accordingly. However, the government does not know the different financial options in the market or what might be offered to any particular procuring firm, if it were allowed to submit bids on different contract lengths. By fixing the contract length at, say, 20 years without any explanation as to why (or market testing for alternative lengths), the government is imposing a constraint on the firm in question, which ultimately could increase consumer prices. This paper presents an auction design that allows the formal introduction of different lengths of contract in a single auction process.

In infrastructure procurement tenders, the government defines and grants rights to private firms to build and/or operate projects that are critical for economic success, as they can give rise to economic growth and productivity. Infrastructure investments are of great importance, but require financial institutions that are willing to provide funding. This has been a demanding challenge for many infrastructure projects, even when the investments are of interest to

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investors. The energy sector is one example. It has been attracting major attention from European governments in the attempt to meet ambitious renewable and decarbonisation targets. UK, for example, might be investing up to £50bn per annum ($77bn) in the period to 2030 (House of Commons Environmental Audit Committee, 2011, p.12).

Within energy an interesting case of infrastructure procurement is that of offshore transmission, i.e. the electrical connection of offshore wind turbines to the onshore grid. Offshore transmission finance is a relatively low risk asset where securing long-term debt on favourable terms is a key issue according to the British energy regulator, Ofgem (Ofgem, 2012a).[1]

In 2009, the first round of tenders for offshore transmission licences was launched by Ofgem followed by second and third rounds in 2012 and 2014. As of late 2015, 15 projects had been auctioned with initial capital values of up to £459m ($707m) each.[2] The tenders gave the participants the opportunity to win licensees so as to own and operate transmission assets. The contracts are for a fixed 20 years of inflation-indexed annual payments.

With the aim of increasing the attractiveness of infrastructure investments in terms of providing capital to finance activities, one solution is to let the length of the regulatory funding period be determined via an auction. Ofgem has considered contract lengths beyond 20 years to make offshore investments more interesting for investors (Ofgem, 2012b, p. 7; DECC, 2012, p. 9). Indeed the question: *"Why 20 years?"* has been asked within the political process (DECC, 2012, Ev 14).

The offshore tenders conducted from 2009 until today can be characterised as a multi-stage process[3], where technical and financial aspects are evaluated by the use of a scoring rule. For the monetary part of the auction (the Tender Revenue Stream, TRS), Ofgem uses a first-score auction, where the lowest TRS is given the highest score (Ofgem, 2009, p. 25; Ofgem, 2011, p. 56). In the field of multidimensional auctions, a first-score auction represents a variant of the first-price auction. The winner of the project for sale delivers the offered quality at the offered price/cost.

This paper presents a sealed-bid auction design - *the Length-of-Contract Auction* (LCA) - which challenges current designs with the aim of providing optimal funding to finance

[1]Another example is highway construction (Engel et al., 1997). These infrastructure projects usually involve significant investments.

[2]This is a final payment that must be paid to the project developer by the winner in the auction to procure the ownership of the asset. Source: https://www.ofgem.gov.uk/electricity/transmission-networks/offshore-transmission/offshore-transmission-tenders Accessed 21 October 2015.

[3]The latest tender process (Round 3) consists of the following stages: an enhanced pre-qualification stage (EPQ), an invitation to tender stage (ITT), a best and final offer stage (if applicable, BAFO), a preferred bidder stage (PB), and a successful bidder stage (SB). In the EPQ, each bidder must complete a questionnaire, which will be evaluated (scored) by Ofgem. One EPQ submission covers one project. If a bidder passes the EPQ stage for a project, it is shortlisted to bid on that project. In the ITT, several factors are considers, including non-monetary factors and monetary factors. Ofgem uses a scoring rule to evaluate the bids, where quality and threshold have a 40% weighting and the TRS has a 60% weighting. If it is not possible to determine a preferred bidder after ITT, Ofgem can use BAFO to determine this preferred bidder. As in ITT, Ofgem uses a scoring rule to evaluate the bids. In the PB and SB, winners are found and licences granted (Ofgem, 2014).

activities.

LCA is a single-unit[4] simultaneous sealed-bid auction design that invites bids for costs with different regulatory guarantee periods, say 22, 25 and 30 years. The auction determines the length of contract to be offered (and the corresponding payment to be paid). In other words, our design makes it possible for the market itself to reveal the desired guarantee periods for different funding opportunities. Under the assumption that a longer contract period could enable a financial institution to offer lower interest rates when lending money, and therefore, result in a lower repayments (in terms of NPV), our design may reduce the financing cost of infrastructure investments.

Our auction design is based on maximising social welfare. This is different from the majority of procurement auctions that have their focus on lowest possible cost (for a given quality). Our auction indirectly combines both aspects into one auction. The purpose for a government is to invest in infrastructure assets to secure delivery of the goods and ensure the reliability of the network. This is clearly important in the energy sector, where the reliability of electricity networks have been referred to as a public good (Kiesling and Giberson, 1997; Joskow and Tirole, 2007; Schulze et al., 2008; DECC, 2014).

LCA is a version of the Vickrey-Clarke-Groves (VCG) mechanism, adapted to our present setup in that the auctioneer announces a vector of utilities and bidders submit a vector of costs, where each element of the vectors represents a contract length. Under the assumption of private values, we demonstrate that the LCA yields efficiency and delivers the optimal length of contract, defined where social value is maximised.

The optimal length of a contract is crucial for governments, although it has been relatively unexplored in the literature. Ausubel and Cramton (2010) discuss an auction that sells different lengths of contracts, but these lengths are pre-defined before start of auction. Ellman (2006) analyses the optimal length of contract in a negotiation environment rather than in an auction. Engel et al. (2001 and 2013) discuss optimal contract lengths in concession contracts. These two papers characterise the optimal contract under full and incomplete information. However, these papers do not test the market for such a contract and do not allow agents to submit a vector of contract lengths.[5]

The closest paper to ours is Klemperer (2010), which studies an auction design, also known as the Product-Mix Auction (PMA), with vector/variety bidding and where the market tests these varieties. PMA is a multi-unit simultaneous sealed-bid design that invites bidders to bid for loans with different collaterals (i.e. varieties). The focus of the PMA is on obtaining the highest interest rates possible subject to supply and demand at each collateral and according to the amount of money available for lending. This differs from the present

[4]It can be extended to more complex situations, including multiple objects and package bidding.

[5]Also Iossa and Martimort (2009) study contract lengths and identify the optimal contract length in procurement, including how a buyer can incentivise the seller through the choice of contract length. However, the buyer does not use an auction to determine the length.

paper for two reasons. Firstly, in PMA the auctioneer does not reveal the utilities before start of auction, as opposed to our design where the revealed true utilities of the auctioneer are used to benchmark the bidders' submitted bid vectors. Secondly, the aim of LCA is on maximising social value as opposed to (directly speaking) revenue maximisation as in PMA. If PMA were applied to a single-unit environment, it would yield efficiency as with LCA. However, the two differences above would still remain.

We contribute to the literature in auction theory by proposing a new design, where the auctioneer - i.e. the government - is participating as an agent and that uses vectors to deliver an efficient outcome and the optimal length of contract, defined where social value is maximised.

This paper is organised as follows. Section 1 illustrates our design with an example. Section 2 presents the general model. Section 3 contains the conclusion.

1. A three-variety example

Consider an auctioneer who wishes to procure a project from a seller (hereafter a bidder). She invites bids for costs (hereafter bids) with different regulatory guarantee periods, i.e. a cost for each length. For simplicity, suppose the auctioneer chooses the periods 20, 25 and 30 years. Hence, a bidder can win the project secured with payment over 20 years, with payment over 25 years, or with payment over 30 years. Suppose we have two bidders. Table 1 shows the submitted bids. For example, bidder 1 has submitted a bid of £353m if the contract length is 20 years, £349m if it is 25 years and £335 if it is 30 years, or written as (353, 349, 335).

Table 1

Submitted bids

Bidder	Length of contract (Years)	Bids (£m)
1	20	353
	25	349
	30	335
2	20	357
	25	332
	30	356

After receiving the bids, a VCG mechanism determines the winner and the length of contract to offer the winning bidder. The mechanism chooses the winner and the contract length, where social value is maximised. Social value is calculated as the difference between the auctioneer's utility of the project and the submitted bids, a social value for each contract length. Suppose the auctioneer's utilities are (364, 357, 350). These are announced before start of auction.

Table 2

Welfare effect

Length of contract (Years)	Auctioneer (£m)	Bidder 1 (£m)	Bidder 2 (£m)	Welfare effect (£m)
20	364	<u>353</u>	357	+11
25	357	349	<u>332</u>	**+25**
30	350	<u>335</u>	356	+15

Table 2 shows that bidder 1 has submitted lowest bids for a contract of 20 years and 30 years. Bidder 2 has submitted lowest bid for a contract of 25 years. The table also shows that social value is maximised if bidder 2 is offered a contract of 25 years (+£25m). Hence, bidder 2 wins the project on a 25-year contract.

We have now determined the winner and the length of contract to offer the winning bidder. In order to determine the payment to offer, we use again the VCG mechanism; we evaluate the welfare effect if the winning bidder was not participating.

Table 3

Welfare effect, without the winner

Length of contract (Years)	Auctioneer (£m)	Bidder 1 (£m)	Welfare effect (£m)
20	364	353	+11
25	357	349	+8
30	350	335	**+15**

Table 3 shows that social value is maximised if the winning bidder (now bidder 1) is offered a contract of 30 years (+£15m). Using VCG, bidder 2 wins the project on a 25-year contract and is given a payment of £342m.[6] In the next section, we introduce the general model, where vectors are of k different versions.

2. The Model

We consider a situation where one project is to be launched. The project can be realized in k different versions. There is one auctioneer (which may be a government, national or local) who invites N bidders to submit bids for carrying out the project. The auctioneer specifies the admissible versions and before the start of the assignment procedure announces a utility vector $\mathbf{u} = (u_1, ..., u_k)$, where u_j is the utility of version j of the project. The utility vector can be seen as signaling the cost that the auctioneer considers as reasonable for carrying out the project, and it may or may not coincide with the true utilities, denoted $\mathbf{v} = (v_1, \ldots, v_k)$.

[6] $-1 \times$ (£350m - £335m) + £357m = £342m.

Each bidder $i \in N = \{1, ..., n\}$ proposes a bid $b^i = (b^i)_{j=1}^k$, $j = 1, ..., k$, for each of the k versions of the project. The bid b^i_j may be seen as the cost to bidder i of providing the jth version of the project. However, the true cost of bidder i, denoted by $c^i = (c^i_1, \dots, c^i_k)$ is private information for the bidder, who may or may not bid truthfully. Let $\mathbf{b} = (b^1, \dots, b^n)$ be the array of bids.

The decision to be found is a pair $d = (i, j) \in N \times K$ consisting of a winning bidder and a version j of the project to be selected. For the auctioneer, we let $u(d) = u_j$ be the utility of this decision according to the announced utilities, and similarly $v(d) = v_j$. For a bidder, we similarly write $b^i(d)$ for the announced value at this decision, meaning that $b^h(d) = 0$ if $h \neq i$. We assume that this decision is found using a mechanism $\mathcal{M}$, a version of the well-known VCG mechanism, adapted to our present setup: Given the utility vector $\mathbf{u}$ announced by the auctioneer and the array $\mathbf{b}$ of bids, the mechanism specifies a decision $d(\mathbf{u}, \mathbf{b})$ and a payment vector $\tau(\mathbf{u}, \mathbf{b})$ specifying a payment t_0 for the auctioneer and a payment t_i, $i = 1, \dots, n$, for each bidder. The decision is found as

$$d(\mathbf{u}, \mathbf{b}) = \text{argmax}_{i,j} = u_j - b^i_j,$$

that is, by maximizing the net utility according to the stated information. The payments are defined as follows, if $d(\mathbf{u}, \mathbf{b}) = d^* = (i^*, j^*)$ then

$$\begin{aligned} t_0(\mathbf{u}, \mathbf{b}) &= \max_{i,j}\{-b^i_j\} + b^{i^*}_{j^*}, & (1)\\ t_i(\mathbf{u}, \mathbf{b}) &= -\max_{h \neq i, j=1,\dots,k}\{u_j - b^h_j\} + (u_{j^*} - 1_{\{i \neq i^*\}} b^{i^*}_{j^*}), i = 1, \dots, n, & (2) \end{aligned}$$

where 1_A is an indicator function taking the value 1 when the statement A is true and 0 otherwise. As usually, the payment reflects the difference in net utility according to the announced utilities and costs of the presence of agent i, $i = 0, 1, \dots, n$. As a somewhat less standard feature, the auctioneer is participating as an agent who announces a utility and is assigned a payment. Also, the payment of the bidders are negative, reflecting that this is an amount of money transferred to the bidder.

The payoff of the auctioneer is defined as $v(d(\mathbf{u}, \mathbf{b})) - t_0(\mathbf{u}, \mathbf{b})$, and the net profit of a bidder i is

$$t_i(\mathbf{u}, \mathbf{b}) - 1_{\{i = i^*\}} c^i_{j^*},$$

since the bidder engages in production and incurs a cost only if winning the auction. It is seen that $t_i(\mathbf{u}, \mathbf{b}) = 0$ if i is not winning.

The mechanism outlined above is a version of the VCG mechanism (see e.g. Krishna, 2009) adapted to our situation, it has the standard properties. We have the following proposition.

Proposition 1 *In the mechanism $\mathcal{M}$, the following hold:*

(i) Truth-telling is a weakly dominant strategy for each of the agents.

(ii) It yields an efficient outcome in the sense that the decision maximises social value.

(iii) It is individually rational for $i = 1, \ldots, n$.

Proof: (i) We first consider the strategy choices of the auctioneer. Suppose that the bidders have submitted $\mathbf{b}$, and the auctioneer has submitted the true utilities $\mathbf{v}$, giving rise to the decision $d(\mathbf{v}, \mathbf{b}) = (i^*, j^*)$, but contemplates to change the message to some $\mathbf{u}$, whereby the decision changes to $d(\mathbf{u}, \mathbf{b}) = (i', j')$. Then, the auctioneer's net payoff satisfies

$$\begin{aligned} v(d(\mathbf{v},\mathbf{b})) - t_0(\mathbf{v},\mathbf{b}) &= v(d(\mathbf{v},\mathbf{b})) - \left[\max_{i,j}\{-b^i_j\} + b^{i^*}_{j^*}\right] \\ &= \left(v(d(\mathbf{v},\mathbf{b})) - b^{i^*}_{j^*}\right) - \max_{i,j}\{-b^i_j\} \\ &\geq \left(v(d(\mathbf{u},\mathbf{b})) - b^{i'}_{j'}\right) - \max_{i,j}\{-b^i_j\} = v(d(\mathbf{u},\mathbf{b})) - t_0(\mathbf{u},\mathbf{b}) \end{aligned}$$

where the inequality follows from the way in which the decision is determined.

For a bidder having submitted true cost c^i and considering a change to b^i, by which the decision changes from (i^*, j^*) to (i', j'), we similarly have that net profit in the case where the bidder is a winner, $i = i^*$, satisfies

$$\begin{aligned} t_i(\mathbf{u}, (b^{-i^*}, c^{i^*})) - c^{i^*}_{j^*} &= -\max_{h\neq i, j=1,\ldots,k}\{u_j - b^h_j\} + u_{j^*} - c^{i^*}_{j^*} \\ &\geq -\max_{h\neq i, j=1,\ldots,k}\{u_j - b^h_j\} + u_{j'} - c^{i'}_{j'} = t_i(\mathbf{u}, (b^{-i^*}, b^{i^*})) - 1_{\{i'=i^*\}}c^{i'}_{j'}. \end{aligned}$$

If the bidder was not a winner, then $t_i(\mathbf{u}, (b^{-i^*}, c^{i^*})) = 0$, and if i becomes a winner by changing to b^i with decision $d(\mathbf{u}, \mathbf{b}) = (i, j')$, then $u_{j^*} - b^{i^*}_{j^*} \geq u_{j'} - c^i_{j'}$, (since (i^*, j^*) was best when i announced true cost), and

$$t_i(\mathbf{u}, \mathbf{b}) - c^i_{j^*} = \left[-\max_{h\neq i, j=1,\ldots,k}\{u_i - b^h_j\} + u_{j'}\right] - c^i_{j'} = -\left(u_{j^*} - b^{i^*}_{j^*}\right) + u_{j'} - c^i_{j'} \leq 0,$$

so that i is as well off telling the truth as with any alternative announcement.

(ii) Since the decision is obtained by maximising the auctioneer's true utility minus the true cost of a bidder, the decision must result in an efficient outcome.

(iii) Individual rationality for the bidders follows from the fact that the bidder's cost is 0 if she chooses not to deliver, which will be the case if the bidder does not win the auction. For the winner at the decision (i^*, j^*), the payment according to (2) is at least equal to $c^{i^*}_{j^*}$. □

Proposition 1 has the following corollary for the case, where the different versions of the project are characterised by the length of the contracts.

Corollary 1 *Let the optimal length of contract be defined as where the social value is maximised. Then, the mechanism $\mathcal{M}$ delivers the optimal length of contract from among the offered k versions.*

Proof: By Proposition 1, $\mathcal{M}$ maximises social value. Therefore, by definition, $\mathcal{M}$ delivers the optimal length of contract. □

Proposition 1 and Corollary 1 have the following corollary.

Corollary 2 *Let $j = 1$ be defined as the shortest contract length to offer, and assume that*

(a) $v_1 > v_a$, $a = 2, ..., k$,

(b) $\max_{h \neq i, a=2,...,k}\{v_a - c_a^h\} > (v_1 - c_1^h)$

Then, the optimal length of contract carries with it a lower payment than the contract with the shortest contract length.

Proof: By Proposition 1, truth-telling is a weakly dominant strategy for each of the agents. By Corollary 1, $\mathcal{M}$ delivers the optimal length of contract. Given assumption (a), it is enough to analyse contracts in connection to v_1. Using assumption (b) and by replacing u_{j^*} in (2) with v_1, where bidder i is the winner, $i = i^*$, with $h \neq i$, we have

$$
\begin{aligned}
t_1^i(v_1, (c_1^{-i^*}, c_1^{i^*})) &= -(v_1 - c_1^h) + v_1 \\
&> -\max_{h \neq i, a=2,...,k}\{v_a - c_a^h\} + v_1 = t_a^i(\mathbf{v}, \mathbf{c})
\end{aligned}
$$

Hence, $\mathcal{M}$ delivers a lower payment than the contract with the shortest contract length. □

The idea is that a longer contract length means lower annual repayments due to a longer amortisation period, and therefore a lower probability of default, and the ability to get a lower interest rate when borrowing money from a financial institution which, when evaluated at the auctioneer's discount rate, lowers payment (inverted yield curve). That said, bidders have different risk profiles and each institution evaluates the project together with a bidder differently. The availability of finance may be non-linear, with the particular institution groupings prepared to offer blocks of finance at different interest rates and maturities depending on their liabilities and risk profile, as contemplated in the corollary.

3. Conclusion

LCA is a single-unit simultaneous sealed-bid auction design that determines the optimal length of contract to offer a winning bidder. The optimal length is the length that maximises social value. Our auction addresses an important drawback in the literature because it, from a welfare point of view, lets the market choose the optimal contract length. The auction is applicable to any infrastructure investment such as, energy, transportation, water or any area that uses longer-term contracts. Further, one could also consider the case where the length of contract is replaced by terms of payment, currency of payment, delivery location, among others. Given that large infrastructure investments can involve billions of pounds of investments being financed privately over long periods, we believe there is significant merit for governments in using our auction, rather than some arbitrary alternative, to determine the optimal financing period.

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